

## **TITLE OF THE INVENTION**

MOUNTING ANGLE DETECTION DEVICE

## **BACKGROUND OF THE INVENTION**

### 5 Field of the Invention

The present invention relates to a device for detecting a mounting angle of a vehicle-mounted device such as a navigation device.

The present application claims priority from Japanese  
10 Patent Application No. 2003-025783, the disclosure of which is incorporated herein by reference in its entirety.

### Description of the Related Art

For instance, a vehicle-mounted navigation device displays guidance by inferentially computing the present  
15 position and bearing based on position information sent by GPS (Global Positioning System) and a traveled distance and bearing information provided by an acceleration sensor and a gyroscopic sensor. However, oblique mounting of the aforementioned acceleration and gyroscopic sensors with inclined detection axes  
20 relative to the vehicle decreases output values. In order to address the problem, various methods have been developed, as disclosed, for example, in JP 2001-153658 A.

Further, a method is known which corrects errors due to the mounting angle by correcting conversion gain of a sensor  
25 such as gyroscopic sensor, as occasion arises, with matching output of the sensor to received GPS data or map data, and then learns the amount of the correction.



Recently, miniaturization of navigation devices has advanced, thereby diversifying the mounting positions such as in-dash areas or spaces below a passenger-side seat. While the mounting position becomes more arbitrary, a navigation device  
5 could be mounted in an inclined fashion with respect to a vehicle. However, inclined mounting, for example mounting the aforementioned navigation device at 30 or more degrees upward to the horizontal, or at 5 or more degrees lateral to the front, significantly decreases the output of a sensor such as a  
10 gyroscopic sensor, thereby making it impossible for the sensor to precisely correct the output thereof. Thus, an adequate range, or permissible range, is preset in the mounting angle of the navigation device.

Because such limitations on the mounting angle of the  
15 navigation device are not generally known, the navigation device may be used with a mounting angle out of the permissible range. In the case where mounting of the navigation device at an angle beyond the permissible range causes errors in the displayed guidance, it may be difficult for a user to recognize a cause  
20 of the errors to provide a required remedy.

Further, in the case where mounting of the navigation device to another position changes the mounting angle accordingly, the navigation device corrects the output of the gyroscopic sensor in accordance with the original mounting angle, thereby  
25 causing errors in the displayed guidance concerning the position and bearing.



## **SUMMARY OF THE INVENTION**

It is a primary object of the present invention to provide a mounting angle detection device for preventing a navigation device and the like from being mounted at an improper mounting angle, or maintaining accuracy of a vehicle-mounted device such  
5 as the navigation device even when the mounting angle is changed due to, for example, any movement of the device, with addressing above problems.

In order to accomplish the aforementioned and other objects,  
10 according to one aspect of the present invention, there is provided a mounting angle detection device for detecting a mounting angle of a vehicle-mounted device mounted in a vehicle, comprising an acceleration sensor mounted in the vehicle-mounted device, and a mounting angle processor.  
15 The mounting angle processor determines a sine value of a mounting angle in a pitch direction of the vehicle-mounted device by dividing a totalized and averaged value by acceleration of gravity. The totalized and averaged value is determined by totalizing and averaging acceleration detected by the  
20 acceleration sensor.

According to another aspect of the present invention, there is provided a mounting angle detection device for detecting a mounting angle of a vehicle-mounted device mounted in a vehicle, comprising an acceleration sensor and a GPS receiver mounted  
25 in the vehicle-mounted device, and a mounting angle processor. The mounting angle processor includes: a pitch angle processor for determining a sine value of a mounting angle in



a pitch direction of the vehicle-mounted device by dividing a totalized and averaged value by acceleration of gravity, the totalized and averaged value being determined by totalizing and averaging acceleration detected by the acceleration sensor; and  
5 a yaw angle processor for determining a cosine value of a mounting angle in a yaw direction of the vehicle-mounted device by subtracting a product of the acceleration of gravity and the sine value of the mounting angle in the pitch direction from acceleration detected by the acceleration sensor to determine  
10 a subtracted value, and then dividing the subtracted value by a value determined by multiplying reference acceleration obtained from the GPS receiver or from a vehicle speed pulse sensor by a cosine value of the mounting angle in the pitch direction.

15 According to yet another aspect of the present invention, there is provided a mounting angle detection device for detecting a mounting angle of a vehicle-mounted device mounted in a vehicle, comprising an acceleration sensor, a GPS receiver and a gyroscopic sensor mounted in the vehicle-mounted device, and  
20 a mounting angle processor. The mounting angle processor includes: a pitch angle processor for determining a sine value of a mounting angle in a pitch direction of the vehicle-mounted device by dividing a totalized and averaged value by acceleration of gravity, the totalized and averaged value being determined  
25 by totalizing and averaging acceleration detected by the acceleration sensor; a sensitivity detector for determining a ratio of angular velocity detected by the gyroscopic sensor to



reference angular velocity obtained from the GPS receiver as sensitivity of the gyroscopic sensor; and a roll angle processor for determining a cosine value of a mounting angle in a roll direction of the vehicle-mounted device by dividing the  
5 determined sensitivity of the gyroscopic sensor by a cosine value of the mounting angle in the pitch direction.

According to yet another aspect of the present invention, there is provided a mounting angle detecting device for a vehicle-mounted device, comprising: a sensitivity detector for  
10 determining a ratio of angular velocity detected by a gyroscopic sensor mounted in the vehicle-mounted device to reference angular velocity obtained from a GPS receiver mounted in the vehicle-mounted device as sensitivity of the gyroscopic sensor; and a comparator for comparing the sensitivity of the gyroscopic  
15 sensor determined by the sensitivity detector to a permissible range concerning the sensitivity and then determining that the mounting angle of the vehicle-mounted device is abnormal when the sensitivity is over the permissible range.

According to yet another aspect of the present invention,  
20 there is provided a mounting angle detecting device for a vehicle-mounted device, comprising: a sensitivity detector for determining a ratio of angular velocity detected by a gyroscopic sensor mounted in a vehicle-mounted device to reference angular velocity obtained from a GPS receiver mounted in the  
25 vehicle-mounted device as sensitivity of the gyroscopic sensor; and a comparator for comparing the sensitivity determined by the sensitivity detector to sensitivity determined last time



by the sensitivity detector and then determining that the mounting angle of the vehicle-mounted device has been changed when the sensitivity determined by the sensitivity detector differs from the sensitivity determined last time.

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#### **BRIEF DESCRIPTION OF DRAWINGS**

These and other objects and advantages of the present invention will become clear from the following description with reference to the accompanying drawings, wherein:

10        Fig. 1 shows a block diagram representing a configuration of a mounting angle detection device according to a first example;

      Fig. 2 shows a relationship between a vehicle-mounted device and a mounting orientation thereof;

15        Fig. 3 shows a block diagram representing a configuration of a mounting angle processor according to the first example;

      Fig. 4 shows a flowchart representing an operation of the mounting angle detection device according to the first example;

20        Fig. 5 shows a block diagram representing a configuration of the mounting angle detection device according to a second example; and

      Fig. 6 shows a flowchart representing an operation of the mounting angle detection device according to the second example.

#### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

25        A preferred embodiment according to the present invention will hereinafter be described with reference to the accompanying drawings. Figure 1 shows a block diagram representing an



exemplary configuration of this mounting angle detection device. Figure 2 shows a relationship between a vehicle-mounted device, i.e. a detection target of this mounting angle detection device, and a mounting orientation thereof. It should be noted that  
5 this mounting angle detection device detects a mounting angle  $\theta$  pitch in the pitch direction, a mounting angle  $\theta$  yaw in the yaw direction, and a mounting angle  $\theta$  roll in the roll direction of the vehicle-mounted device 101.

In Fig. 1, this mounting angle detection device comprises  
10 an acceleration sensor 1 for detecting and outputting acceleration, a gyroscopic sensor 2 for detecting angular velocity around a detection axis, a GPS receiver 3 for outputting position information based on received data from GPS satellites, a mounting angle processor 4 for determining the mounting angle  
15 of the vehicle-mounted device 101, a storage 5, a comparator 6, notifying means 7, and updating means 8. It should be noted that the acceleration sensor 1, the gyroscopic sensor 2, and the GPS receiver 3 are provided in the vehicle-mounted device 101.

20 This mounting angle detection device with the above configuration operates in a manner as described below. First, the mounting angle processor 4 determines a sine value  $\sin(\theta$  pitch) of a mounting angle in the pitch direction by dividing a totalized and averaged value  $A_{ave}$  of the detected acceleration  
25 of the acceleration sensor 1 by the acceleration of gravity  $g$ .

Then, the mounting angle processor 4 determines a cosine value  $\cos(\theta$  yaw) of a mounting angle in the yaw direction by



subtracting a product  $g \times \sin(\theta \text{ pitch})$  of the acceleration of gravity  $g$  and the sine value of the mounting angle in the pitch direction from the acceleration  $A_s$  obtained from the acceleration sensor 1, and then dividing it by a product  $A_r \times \cos(\theta \text{ pitch})$  of vehicle acceleration  $A_r$  obtained from the GPS receiver 3 and a cosine value of the mounting angle in the pitch direction, .

Further, the mounting angle processor 4 determines a ratio of  $\omega_s$  to  $\omega_r$  as sensitivity  $S_g$  of the gyroscopic sensor 2, wherein  $\omega_s$  is an angular velocity detected by the gyroscopic sensor 2, and  $\omega_r$  is a reference value of an angular velocity obtained from the GPS receiver 3. The mounting angle processor 4 subsequently determines a cosine value  $\cos(\theta \text{ roll})$  of the mounting angle in the roll direction by dividing the sensitivity  $S_g$  by the cosine value  $\cos(\theta \text{ pitch})$  of the mounting angle in the pitch direction.

Then, the comparator 6 compares the detected mounting angles  $\theta \text{ pitch}$ ,  $\theta \text{ yaw}$  and  $\theta \text{ roll}$  to the respective permissible ranges. When the mounting angles are over the respective permissible ranges, the notifying means 7 notifies the user of an abnormality of the mounting angles.

Further, the comparator 6 compares the detected mounting angles to the respective mounting angles detected by the last detecting operation and stored in the storage 5 respectively, to determine that the mounting angles have been changed if the obtained mounting angles are different from the last values. On such a determination, the notifying means 7 notifies the user of the change of the mounting angles. The updating means 8



subsequently resets a function of learning parameters for correcting the output of the sensor, thereby updating the correcting parameters to those relative to the changed mounting angle. Alternatively, the notifying means 7 may output a  
5 notification advising the user to reset the learning function.

The mounting angle detection device according to the present embodiment with the aforementioned configuration determines the mounting angles  $\theta$  pitch,  $\theta$  yaw and  $\theta$  roll of the vehicle-mounted device 101 based on the changes of the output  
10 of the acceleration sensor 1 and gyroscopic sensor 2, and then notifies the user of the abnormality of the mounting angles when the detected mounting angles are over the respective permissible ranges. Thus, the user can recognize the abnormality of the mounting angles of the vehicle-mounted device 101. In other  
15 words, this mounting angle detection device prevents the vehicle-mounted device 101 from being mounted at any improper angle.

Moreover, this mounting angle detection device detects the changes of the mounting angles by comparing the detected  
20 mounting angles to the previous mounting angles detected last time, respectively. On detecting the change of the mounting angle, the mounting angle detection device resets the function for learning the correcting parameters of the sensor, and updates the correcting parameters to those relative to the changed  
25 mounting angles, thereby maintaining the accuracy of the vehicle-mounted device 101, even in a case where the mounting angles have been changed, by correcting the output with respect



to the changed mounting angles.

(First Example)

A first preferred example according to the present invention will be hereinafter described with reference to the accompanying drawings. It should be noted that the description of this example will be made on the mounting angle detection device for detecting the mounting angle of a navigation device 101 mounted in the vehicle 100.

As shown in Fig. 1, this mounting angle detection device comprises an acceleration sensor 1 for detecting and outputting acceleration, a gyroscopic sensor 2 for detecting angular velocity around a detection axis, a GPS receiver 3 for outputting position information based on received data from GPS satellites, a mounting angle processor 4 for determining the mounting angle of the navigation device 101, a storage 5, a comparator 6, notifying means 7, and updating means 8.

The acceleration sensor 1, the gyroscopic sensor 2, and the GPS receiver 3 provided in this mounting angle detection device are sensors mounted on the navigation device 101. It should be noted that these sensors might be provided separately in the navigation device 101.

The mounting angle processor 4 is configured so as to determine the mounting angle  $\theta$  pitch in the pitch direction the mounting angle  $\theta$  yaw in the yaw direction and the mounting angle  $\theta$  roll in the roll direction based on signal information obtained from the acceleration sensor 1, gyroscopic sensor 2, and GPS receiver 3. The detailed configuration will be discussed later.



The storage 5 is a storing device capable of storing and rewriting information therein, and stores the mounting angles  $\theta$  pitch,  $\theta$  yaw and  $\theta$  roll detected by the mounting angle processor 4. It should be noted that mounting angles detected by the last  
5 detecting operation and stored in the storage 5 are represented as  $\theta$  pitch\*,  $\theta$  yaw\* and  $\theta$  roll\*, respectively.

The comparator 6 compares the mounting angle detected by the mounting angle processor 4 to a preset value to make a determination.

10 The notifying means 7 notifies the user of a message concerning an abnormality of the mounting angles via display monitor provided in the navigation device 101 or via a sound.

The updating means 8 updates parameters, such as conversion gain, for correcting the output of the acceleration sensor 1  
15 and the gyroscopic sensor 2.

The configuration of the mounting angle processor 4 is now described in detail. Figure 3 shows a block diagram representing a configuration of the mounting angle processor 4. In this figure, the mounting angle processor 4 comprises  
20 a pitch angle processor 41, a yaw angle processor 42, a gyroscopic sensor sensitivity detector 43, and a roll angle processor 44.

The pitch angle processor 41 is configured so as to determine the mounting angle  $\theta$  pitch in the pitch direction by totalizing and averaging the output  $A_s$  of the acceleration sensor  
25 1 to calculate a totalized and averaged value  $A_{ave}$  and then dividing the totalized and averaged value  $A_{ave}$  by the acceleration of gravity  $g$ .



The yaw angle processor 42 is configured so as to determine a cosine value  $\cos(\theta_{\text{yaw}})$  of a mounting angle in the yaw direction by subtracting a product  $g \times \sin(\theta_{\text{pitch}})$  of the acceleration of gravity  $g$  and the sine value of the mounting angle in the pitch direction from the acceleration  $A_s$  obtained from the acceleration sensor 1, and then dividing it by a product  $A_r \times \cos(\theta_{\text{pitch}})$  of acceleration  $A_r$  obtained based on the position information from the GPS receiver 3 and a cosine value of the mounting angle in the pitch direction. It should be noted that a configuration is also possible which utilizes pulse signals generated by a vehicle speed sensor, i.e. a sensor for generating a pulse signal every predetermined distance of driving of the vehicle 100, as input and then determines the above reference acceleration  $A_r$  based on temporal rate of change concerning the pulse signals.

The gyroscopic sensor sensitivity detector 43 is configured so as to determine an angular velocity  $\omega_r$  (reference angular velocity) around a pivot based on the position information from the GPS receiver 3 and then obtain a ratio of the reference angular velocity  $\omega_r$  to an angular velocity  $\omega_s$  outputted by the gyroscopic sensor 2 as sensitivity  $S_g$  of the gyroscopic sensor 2.

The roll angle processor 44 is configured so as to determine a mounting angle  $\theta_{\text{roll}}$  in the roll direction by dividing the sensitivity  $S_g$  of the gyroscopic sensor 2 by the cosine value  $\cos(\theta_{\text{pitch}})$  of the mounting angle in the pitch direction.

The operation of this mounting angle detection device with the above configuration is now described with reference to a



flowchart shown in Fig. 4.

For instance, when the navigation device is switched on, the detecting operation according to this mounting angle detection device is initiated, and in step S1 the mounting angle operator 4 detects the mounting angles  $\theta$  pitch,  $\theta$  yaw and  $\theta$  roll of the navigation device 101. The mounting angle processor 4 operates in a following manner.

$$\sin(\theta \text{ pitch}) = A_{ave} / g \dots\dots\dots (1)$$

First, the pitch angle processor 41 totalizes the output As of the acceleration sensor 1 to determine an averaged value  $A_{ave}$  when the vehicle is, for example, stationary or travels at a constant speed, i.e. the component of the acceleration in the direction of travel is zero. As expressed by the equation (1),  $\sin(\theta \text{ pitch})$  equivalent to the mounting angle in the pitch direction is obtained by dividing the averaged value  $A_{ave}$  by the acceleration of gravity  $g$ .

$$As_x = As - g \times \sin(\theta \text{ pitch}) \dots\dots\dots (2)$$

$$\cos(\theta \text{ yaw}) = As_x / (Ar \times \cos(\theta \text{ pitch})) \dots\dots\dots (3)$$

As expressed by the equation (2), the yaw angle processor 42 removes subsequently the effect of the acceleration of gravity  $g$  in the direction of the detection axis of the acceleration sensor by subtracting a product  $g \times \sin(\theta \text{ pitch})$  of the acceleration of gravity  $g$  and the sine value of the mounting angle in the pitch direction, from the acceleration  $As$  obtained from the acceleration sensor 1. Then, the position information obtained from the GPS receiver 3 is inputted, and the reference acceleration  $Ar$  is determined based on the amount of temporal



change of position, thereby, as expressed by the equation (3), determining the cosine value  $\cos(\theta_{\text{yaw}})$  corresponding to the mounting angle in the yaw direction by dividing the acceleration without the gravitational effect by the product  $A_r \times \cos(\theta_{\text{pitch}})$  of the reference acceleration  $A_r$  and a cosine value of the mounting angle in the pitch direction.

$$S_g = \omega_s / \omega_r \dots\dots (4)$$

$$\cos(\theta_{\text{roll}}) = S_g / \cos(\theta_{\text{pitch}}) \dots\dots (5)$$

The gyroscopic sensor sensitivity detector 43 employs the position information obtained from the GPS receiver 3, and determines the reference angular velocity  $\omega_r$  around the pivot of the vehicle based on the amount of temporal change of the bearing. Then, as expressed by the equation (4), a ratio of the output  $\omega_s$  of the gyroscopic sensor to the reference angular velocity  $\omega_r$  is determined as sensitivity  $S_g$  of the gyroscopic sensor 2. In other words, the sensitivity  $S_g$  of the gyroscopic sensor 2 may be referred to as the rate of decrease of output  $\omega_s$  of the gyroscopic sensor 2 to the actual angular velocity  $\omega_r$ .

The roll angle processor 44, as expressed by the equation (5), determines  $\cos(\theta_{\text{roll}})$  corresponding to the mounting angle in the roll direction by dividing the sensitivity  $S_g$  of the gyroscopic sensor 2 by the cosine value  $\cos(\theta_{\text{pitch}})$  of the mounting angle in the pitch direction.

According to this processing, the mounting angle processor 4 determines the mounting angles  $\theta_{\text{pitch}}$ ,  $\theta_{\text{yaw}}$  and  $\theta_{\text{roll}}$  of the navigation device 101.



Then, in step S2 in the flowchart shown in Fig. 4, the comparator 6 compares the detected mounting angles to the angles defining the respective permissible ranges. When the comparator 6 determines that at least one of the mounting angles  
5  $\theta$  pitch,  $\theta$  yaw and  $\theta$  roll is out of the permissible range, the processing advances to step S3. In step S3, the notifying means 7 notifies the user via display monitor of the navigation device 101 or via a sound that the navigation device 101 is mounted at an angle out of the permissible range, i.e., the mounting  
10 angle is abnormal. It should be noted that the notification might advise the user to position the navigation device 101 within the permissible range.

In step S4, the comparator 6 compares the detected mounting angles  $\theta$  pitch,  $\theta$  yaw and  $\theta$  roll to the respective last value  
15  $\theta$  pitch\*,  $\theta$  yaw\* and  $\theta$  roll\* stored in the storage 5. In this step, if at least one of differences between the mounting angles and the respective last values exceeds a preset amount, the comparator 6 determines that the mounting angle has been changed.

Then, if so, in step S5, the notifying means 7 notifies  
20 the user via display monitor that the mounting angle of the navigation device 101 has been changed.

Subsequently, in step S6, the updating means 8 resets the learning function of the navigation device 101, thereby updating the parameters correcting the output of the acceleration sensor  
25 1 or gyroscopic sensor 2, for example conversion gain, to the values relative to the changed mounting angles.

The above correcting parameters are determined by the



learning function of the navigation device 101. In other words, the aforementioned learning function determines the correcting parameter without deviation components by totalizing and averaging the amount of correction with comparing the output of the acceleration sensor 1 or gyroscopic sensor 2 to the position or map information from the GPS receiver. The navigation device 101 corrects the errors of the acceleration sensor 1 or gyroscopic sensor 2 occurring due to the mounting angles, by utilizing the correcting parameters.

10 In other words, in step 6, the updating means 8 resets the aforementioned learning function to initialize the amount of correction accumulated based on the mounting angles before change, thereby restarting the learning function relative to the changed mounting angle.

15 It should be noted that the aforementioned learning function might be provide in the updating means 8 instead of the navigation device 101. In this case, when detection of any change in the mounting angles in step S4 causes the processing to advance to S6, the updating means 8 may reset the aforementioned learning function, thereby providing the navigation device 101 with the true values. The true values are obtained by correcting the output of the acceleration sensor 1 and gyroscopic sensor 2 as follows.

$$A = G1 \times (As - C1) \dots\dots (6)$$

25 
$$= 1 / (\cos(\theta \text{ pitch}) \times \cos(\theta \text{ yaw}))$$
$$\times (As - g \times \sin(\theta \text{ pitch})) \dots\dots (7)$$

$$\omega = G2 \times \omega s \dots\dots (8)$$



$$= 1 / (\cos(\theta \text{ pitch}) \times \cos(\theta \text{ roll})) \times \omega s \dots\dots\dots (9)$$

Forexample, the updating means 8 transforms the conversion gain G1 and the offset C1 for converting the output As of the acceleration sensor 1 to the true value A as expressed by the equation (6), into the values relative to the mounting angles  $\theta$  pitch and  $\theta$  yaw as expressed by the equation (7), and provides the navigation device 101 with the true value A obtained by correcting the output As of the acceleration sensor 1 based on the transformed conversion gain G1 and offset C1. Further, the updating means 8 transforms the conversion gain G2 for converting the output  $\omega s$  of the gyroscopic sensor 2 to the true value  $\omega$  as expressed by the equation (8), into the values relative to the mounting angles  $\theta$  pitch and  $\theta$  roll, and provides the navigation device 101 with the true value  $\omega$  obtained by correcting the output  $\omega s$ .

Finally, in step S7, the determined mounting angles  $\theta$  pitch,  $\theta$  yaw and  $\theta$  roll are stored in the storage 5. The stored mounting angles will be used as the last values for comparison in step S4 concerning the next detecting operation.

As described above, the mounting angle detection device according to the present example detects the mounting angles  $\theta$  pitch,  $\theta$  yaw and  $\theta$  roll of the navigation device 101 based on the changes in the output of the acceleration sensor 1 and gyroscopic sensor 2. Then, if any of the detected mounting angles is out of the permissible ranges, the user is notified of the abnormality of the mounting angles. Even if the navigation device 101 is mounted at a mounting angle out of the permissible



range and thus an error occurs in the displayed guidance, the user can recognize the cause and apply an appropriate remedy. Consequently, this mounting angle detection device can prevent the navigation device 101 from being mounted at a mounting angle  
5 out of the permissible range.

Further, this mounting angle detection device detects the change in the mounting angles by comparing the detected mounting angles to the previous mounting angles detected last time. When the change in the mounting angles is detected, the parameters  
10 for correcting the output of the sensor are updated based on the values detected this time, thereby maintaining the accuracy of the displayed guidance of the navigation device 101 even in a case where the mounting angles are changed.

Further, this mounting angle detection device resets and  
15 restarts the aforementioned learning function for determining the parameters when detecting the change in the mounting angle, thereby obviating the necessity for the user to reset the function and maintaining the accuracy of the displayed guidance of the navigation device 101.

20 It should be noted that the comparator 6 might detect the abnormality and change in the mounting angles by comparing the sine value  $\sin(\theta_{\text{pitch}})$  of the mounting angle in the pitch direction, the cosine value  $\cos(\theta_{\text{yaw}})$  of the mounting angle in the yaw direction, and the cosine value  $\cos(\theta_{\text{roll}})$  in the  
25 roll direction to the respective permissible ranges or to the respective values detected last time.

(Second Example)



A second preferred example according to the present invention will be hereinafter described with reference to the accompanying drawings. It should be noted that the same elements as those of the first example or the elements corresponding to those of the first embodiment are referenced with the same symbols.

Figure 5 shows an block diagram representing a configuration according to this mounting angle detection device. In this figure, the mounting angle detection device comprises a gyroscopic sensor 2, a GPS receiver 3, a gyroscopic sensor sensitivity detector 43, a storage 5, a comparator 6, notifying means 7, and updating means 8.

The operation of this mounting angle detection device is now described with reference to a flowchart shown in Fig. 6.

When the detecting operation according to this mounting angle detection device is initiated, the gyroscopic sensor sensitivity detector 43 determines the reference angular velocity  $\omega_r$  around the pivot of the vehicle based on the amount of temporal change of the bearing in the position information from the GPS receiver 3 in step S11, and determines the ratio of the output  $\omega_s$  of the gyroscopic sensor 2 to the reference angular velocity  $\omega_r$  as sensitivity  $S_g$  of the gyroscopic sensor 2.

Next, in step S12, the comparator 6 compares the aforementioned sensitivity  $S_g$  of the gyroscopic sensor 2 to the permissible range of the sensitivity. The permissible range is set in a range of sensitivity allowing the navigation device



101 to display accurate guidance. The comparator 6 determines that the mounting angles of the navigation device 101 are abnormal if the sensitivity  $S_g$  of the gyroscopic sensor 2 is out of the permissible range.

5           Then, in step S13, the notifying means 7 notifies the user via the display monitor that the mounting angles of the navigation device 101 are abnormal.

          Further, in step S14, the comparator 6 compares the detected sensitivity  $S_g$  of the gyroscopic sensor 2 to the stored  
10   sensitivity  $S_g^*$  determined by the last detecting operation. The comparator 6 determines that the mounting angles are changed if the difference between the sensitivity  $S_g$  of the gyroscopic sensor 2 and the last sensitivity  $S_g^*$  stored in the storage 5 exceeds the preset amount.

15           Then, in step S15, the notifying means 7 notifies the user via the display monitor that the mounting angles of the navigation device 101 have been changed.

          In step S16 subsequent to the step S15, the updating means 8 resets the learning function for determining the parameters  
20   for correcting the output of the gyroscopic sensor 2, thereby updating the correcting parameter to those relative to the changed mounting angles.

          Finally, in step S17, the determined sensitivity  $S_g$  of the gyroscopic sensor 2 is stored in the storage 5.

25           The mounting angle detection device according to the present second example detects the sensitivity  $S_g$  of the gyroscopic sensor 2, and determines the abnormality of the



mounting angles of the navigation device 101 based on the sensitivity  $S_g$ . On detection of the abnormality of the mounting angles, the user is notified of the abnormality. Even if the navigation device 101 is mounted at an improper mounting angle  
5 out of the permissible range and thus an error occurs in the displayed guidance, the user can recognize the cause and apply an appropriate remedy. Consequently, this mounting angle detection device can prevent the navigation device 101 from being mounted at an improper mounting angle.

10 Further, this mounting angle detection device detects the change of the mounting angles by comparing the detected sensitivity  $S_g$  of the gyroscopic sensor to the sensitivity  $S_{g^*}$  detected last time. On detecting the change of the mounting angle, the mounting angle detection device resets the function  
15 for learning the correcting parameters of the sensor, and updates the correcting parameters to those relative to the changed mounting angles, thereby maintaining the accuracy of the navigation device 101, even in a case where the mounting angles have been changed.

20 Moreover, on detecting a change of the mounting angles, the present mounting angle detection device resets and restarts the aforementioned learning function for determining the parameters, thereby maintaining the accuracy of the displayed guidance of the navigation device 101 without any reset operation  
25 by the user.

While the presently preferred embodiments of the present invention have been shown and described, it is to be understood



that these disclosures are for the purpose of illustration and that various changes and modifications may be made without departing from the scope of the invention as set forth in the appended claim.